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14. ABSTRACT

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MEMORANDUM FOR PR (In-House Publication)
FROM: PROI (TI) (STINFO)

06 March 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2000-044**
Miller, Timothy C., Liu, C.T., "Pressure Effects and Fracture of a Rubbery Particulate Composite"

Society for Experimental Mechanics (SEM) IX Internat'l Congress **(Statement A)**
(Orlando, FL 5-8 Jun 00)(Deadline: 04 Jun 2000)

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ROBERT C. CORLEY (Date)
Senior Scientist (Propulsion)
Propulsion Directorate

The Effects of Pressure on Fracture of a Rubbery Particulate Composite

T. C. Miller and C. T. Liu

Air Force Research Laboratory

Edwards Air Force Base, California

SEM IX International Congress

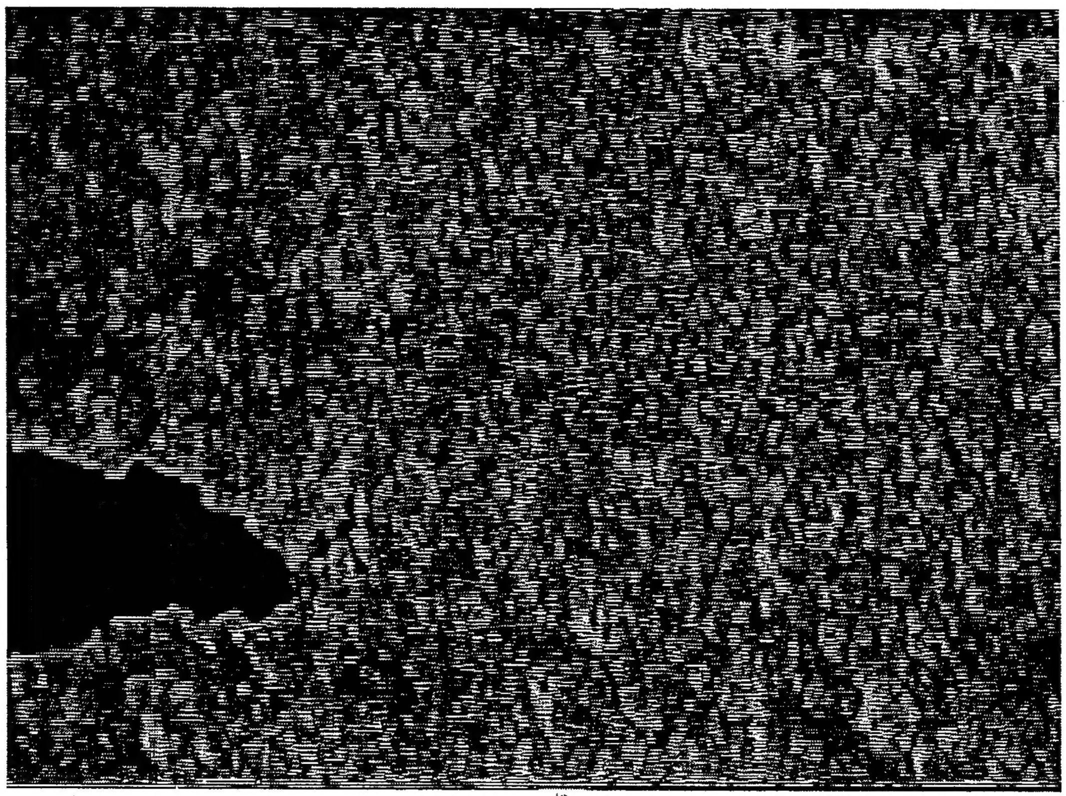
Orlando, Florida

June 5-8, 2000

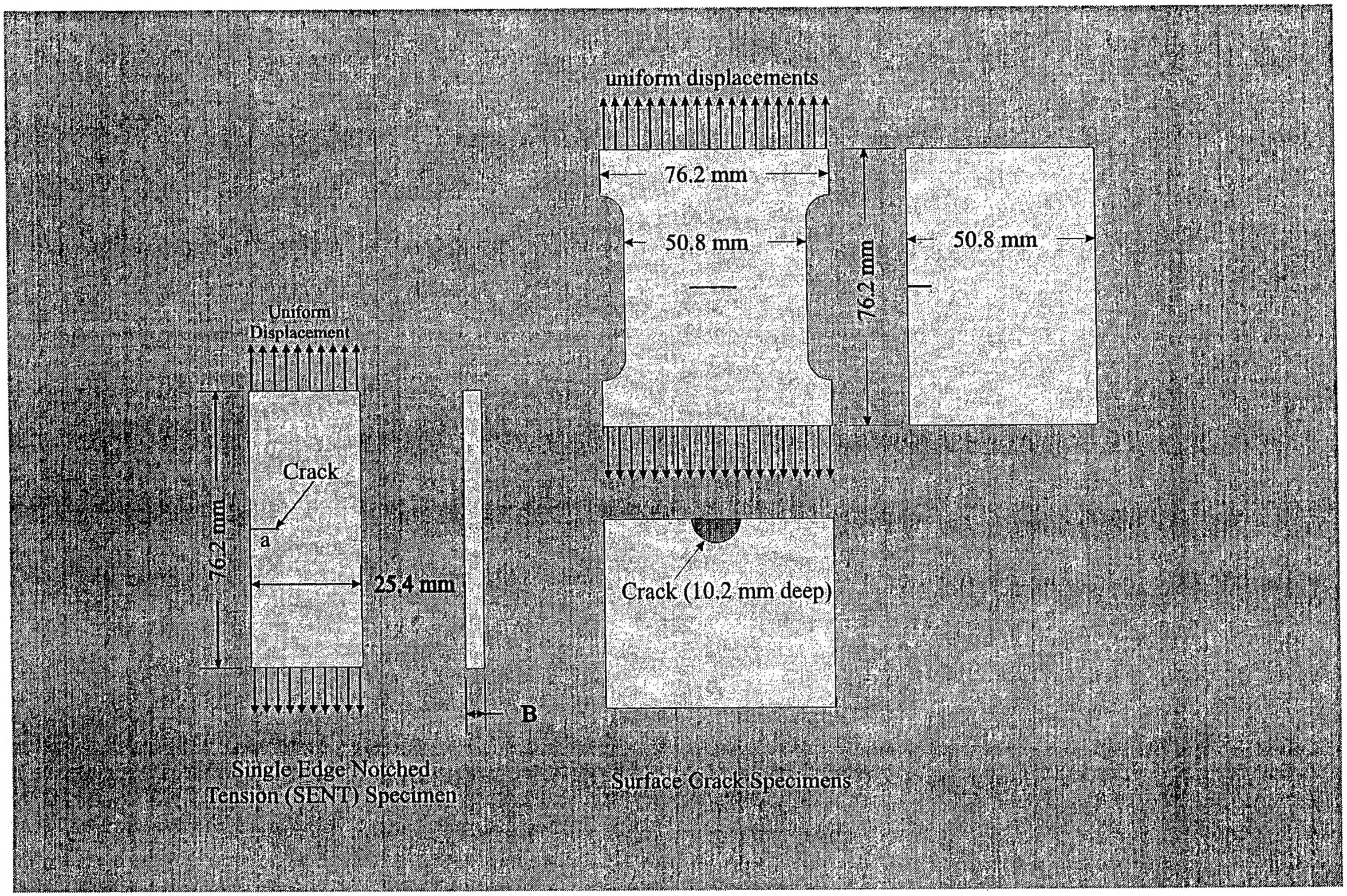
AIR FORCE RESEARCH LABORATORY

Introduction

- Need for studying effect of pressure
- Materials involved



Geometries Used in Testing

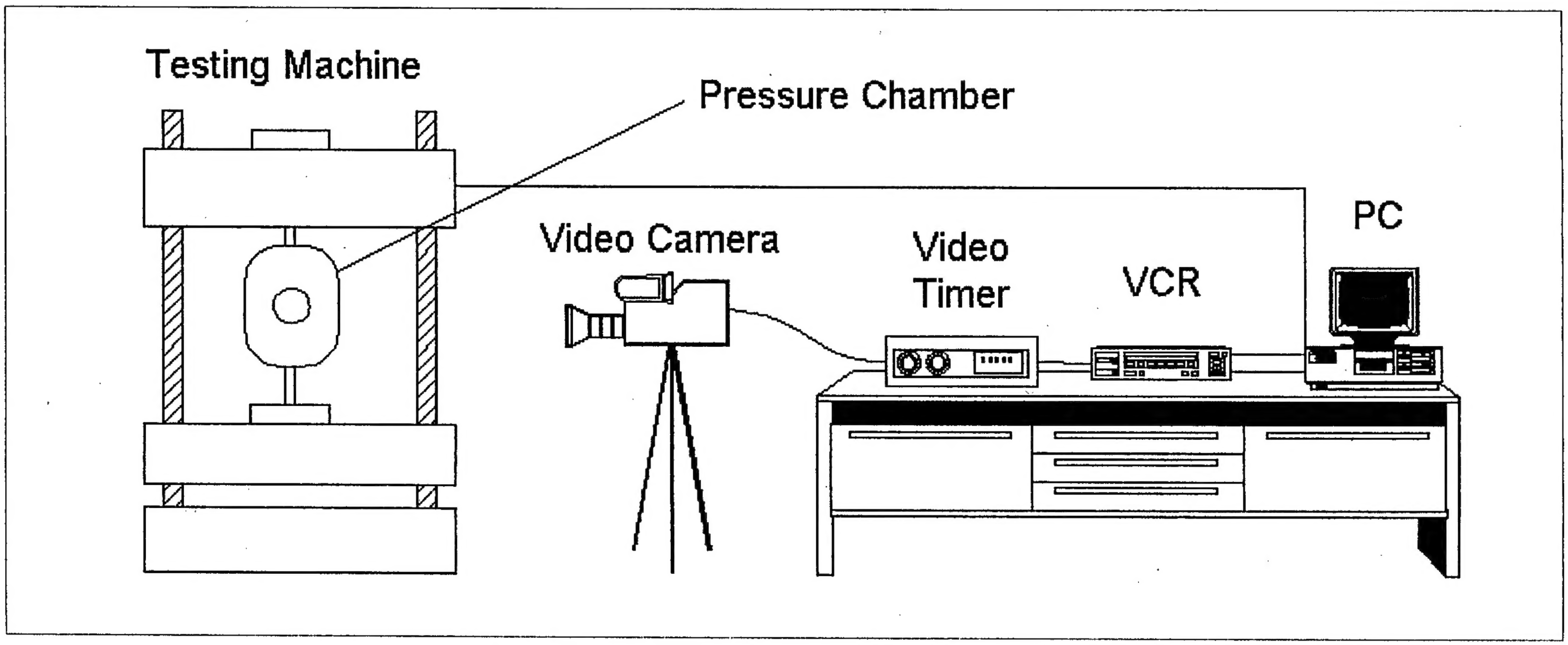


Test Matrix for Pressure Tested Specimens

Number of SENT specimens tested	a_0 [mm] / B [mm]	2.54	7.62	12.70
	5.08	3	3	3
	12.70	3	3	3
	38.10	3	3	3
Number of surface crack specimens	6			

Experimental Method

- Test pressure of 6894 kPa
- Constant strain rate of 0.067 mm/mm/min.
- Room temperature
- Both single edge notched tension (SENT) and surface cracked specimens were tested



Modeling Issues

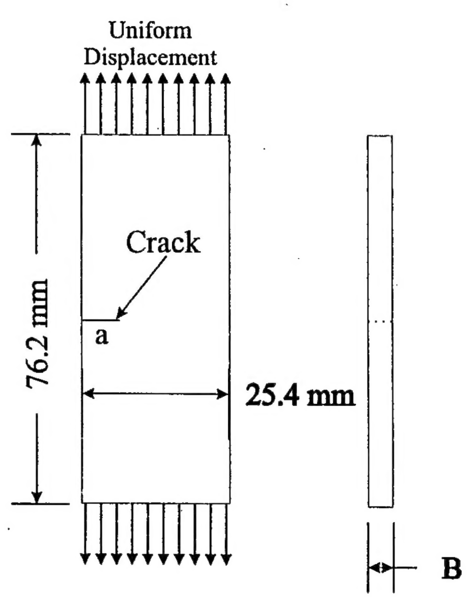
- Displacement controlled boundary conditions
- Use of hybrid elements for incompressible materials
- Domain integral method $\Rightarrow J \Rightarrow K_{Ii}$
- Geometric correction factor from $K_{Ii} / [\sigma(\pi a)^{1/2}]$

Geometric Correction Factors Used

SENT Geometry (a/w ratio varies)

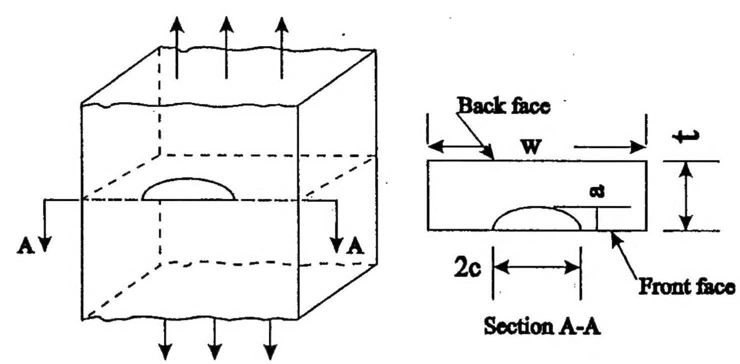
$$K_I = \sigma\sqrt{\pi a}\, f(a/w)$$

$$f(a/w) = 2.694\left(\frac{a}{w}\right)^3 - 1.949\left(\frac{a}{w}\right)^2 + 1.327\left(\frac{a}{w}\right) + 1.008$$



Surface Crack Geometry (fixed crack geometry)

$$K_I = \sigma\sqrt{\pi a}\,(0.6720)$$



Results

- Determination of stress intensity factor at growth initiation
- Determination of subsequent crack growth rate
- Comparisons with ambient pressure data

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The Process of Crack Growth Initiation

- Definition of initiation toughness: the *fracture initiation toughness* is defined as the stress intensity factor at the point in time at which the crack begins actual growth
- Prior to this point, significant blunting may occur
- Substantial crack growth can also occur
- Use of videotape images to determine onset of crack growth
- Determination of initiation toughness based on test machine data and correction factors

Determining Initiation Toughnesses

Initiation toughness is found using regression method

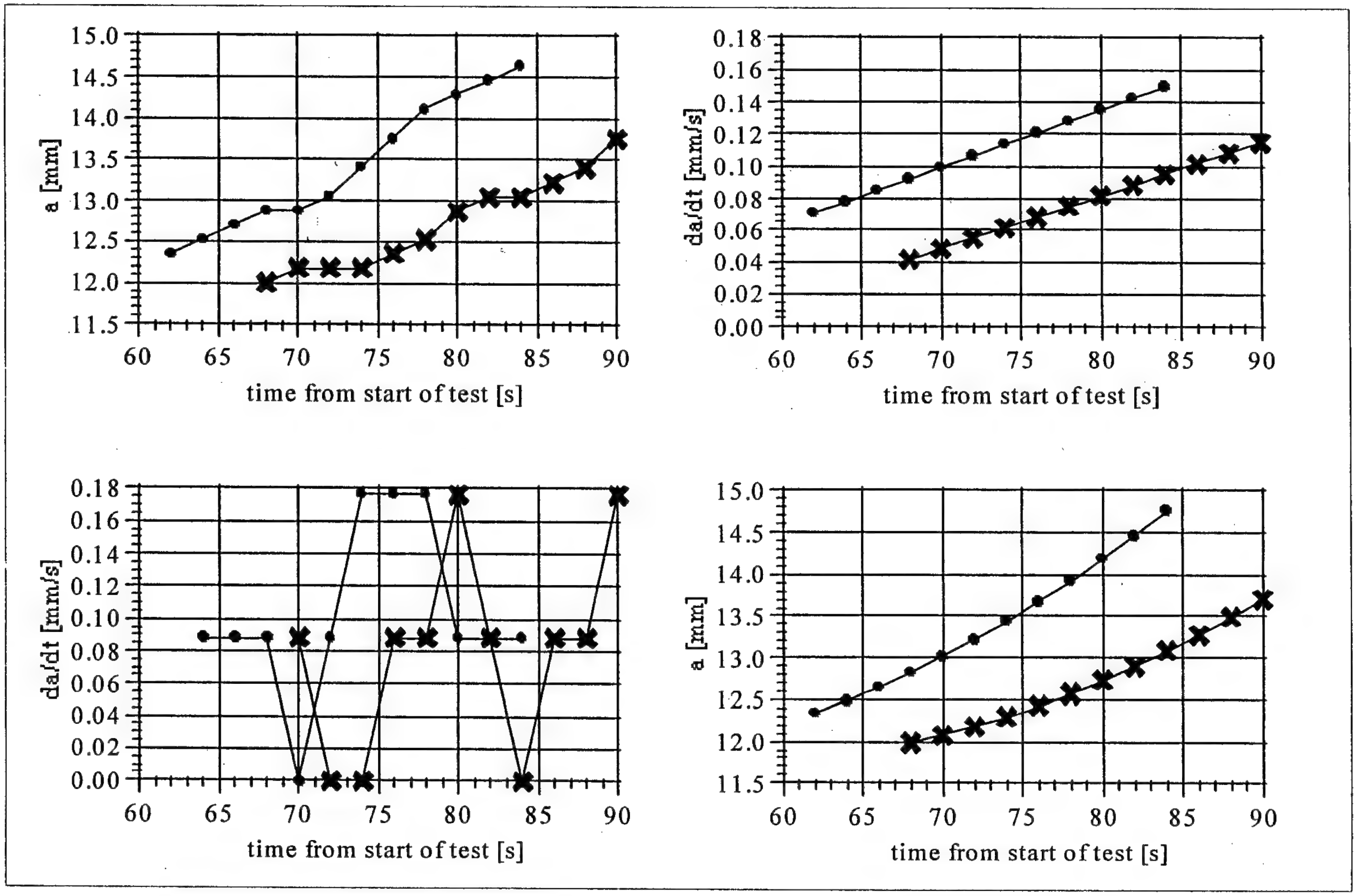
$$K_I = \sigma \sqrt{\pi a}\, f(a/w)$$

$$\sigma = \frac{K_I}{\sqrt{\pi a}\, f(a/w)}$$

Complications in Determining Crack Growth Rates

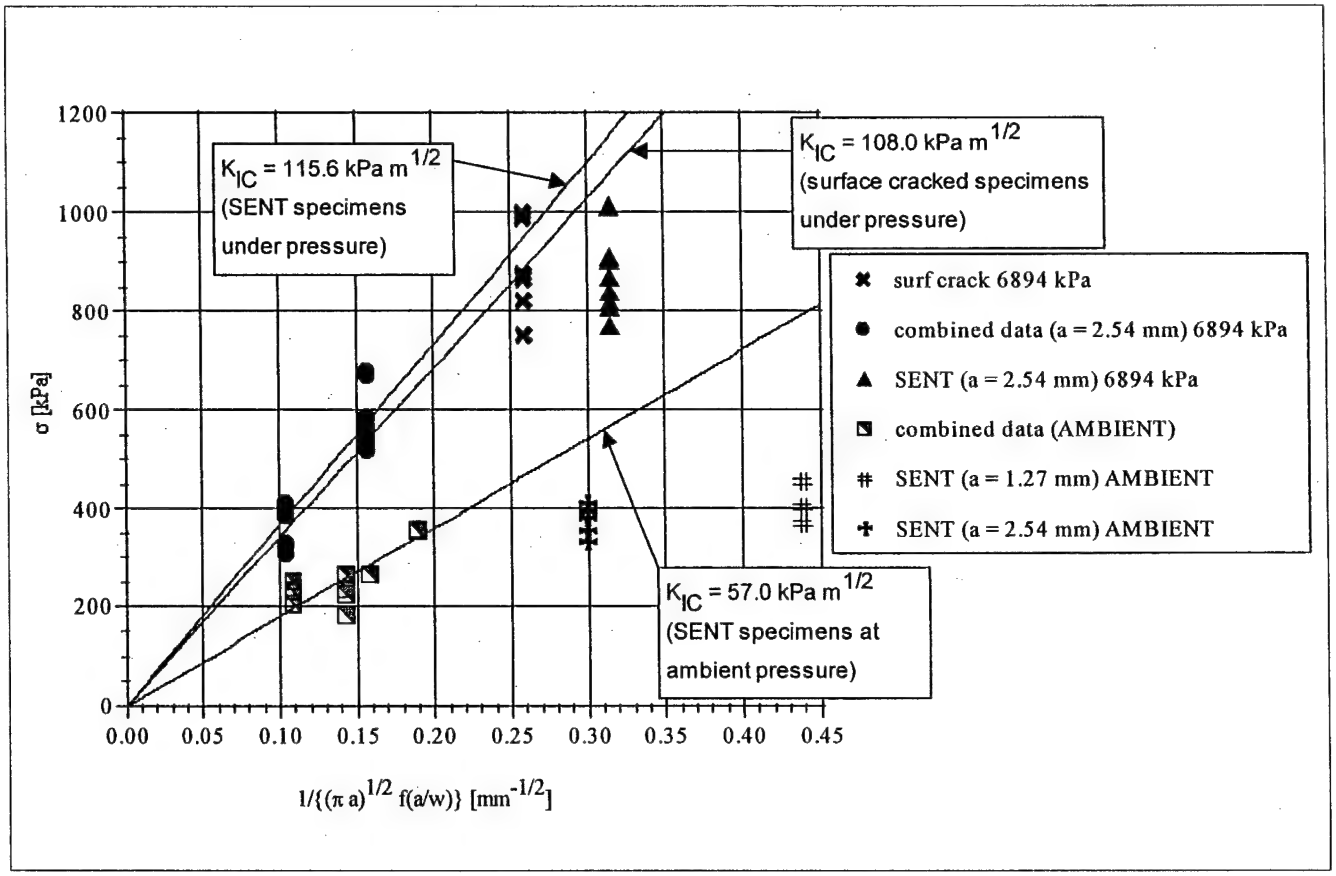
Secant method

Polynomial method

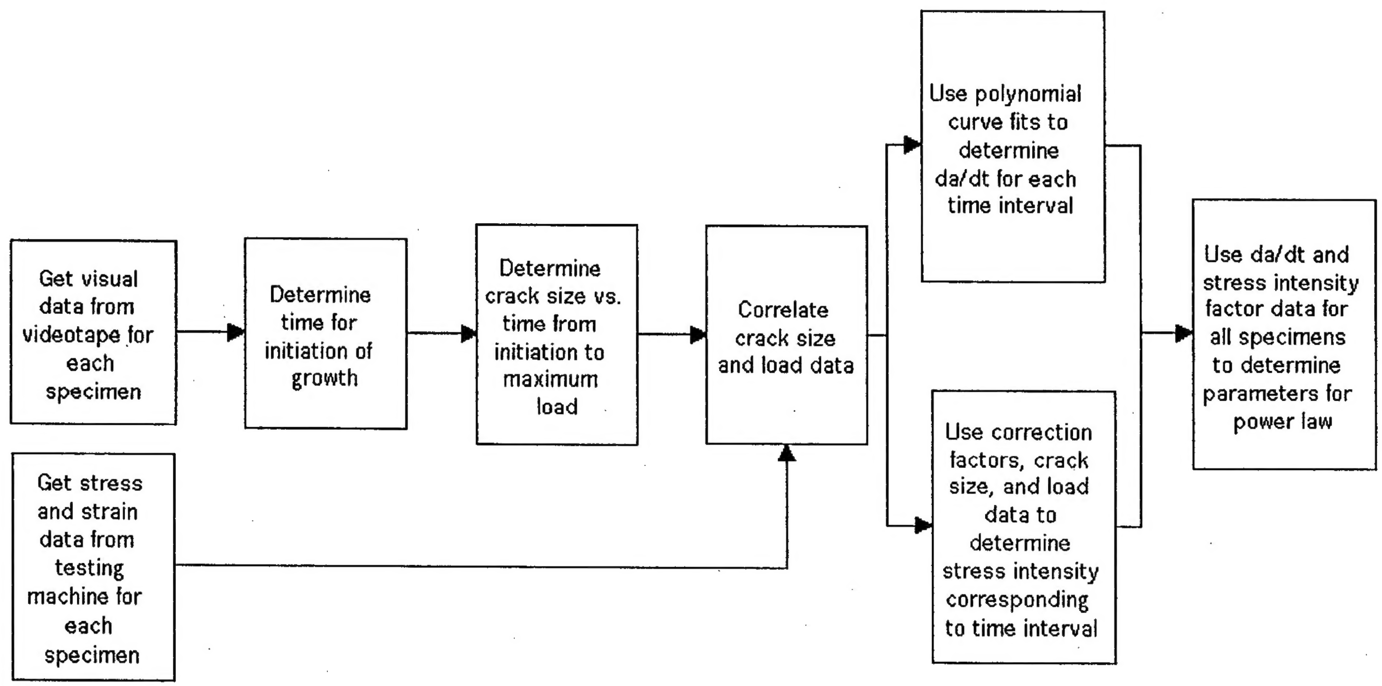


Initiation Toughness Results

- Results give approximate threshold crack size
- Effect of pressure is to elevate initiation toughness
- SENT and surface cracked specimens give similar results



Determining Crack Growth Rates



Result for Pressurized Environment:

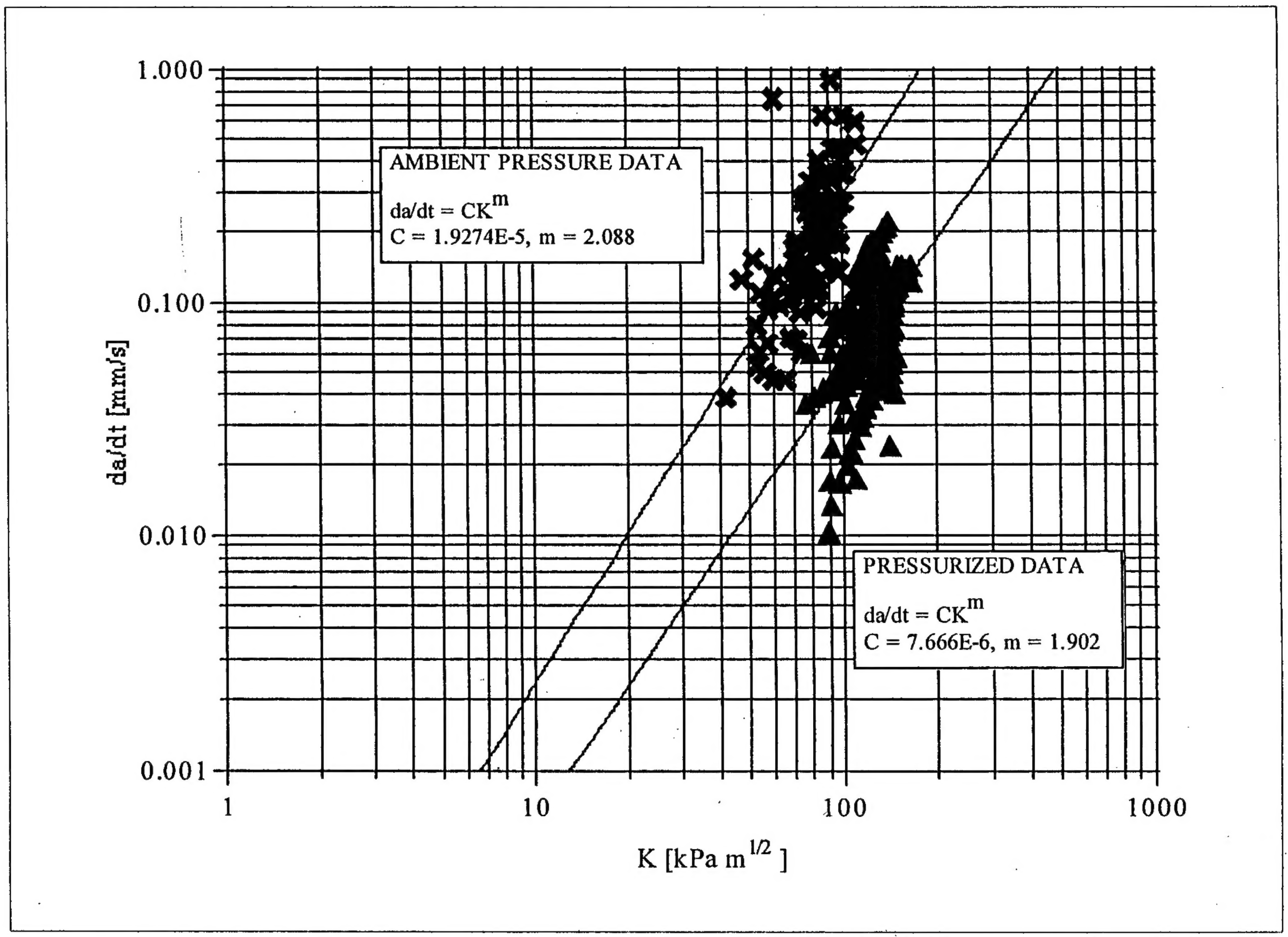
$$\frac{da}{dt} = CK_I^m \text{ (units of mm/s and kPa}\sqrt{\text{m}}\text{)}$$

$$C = 7.67E-06$$

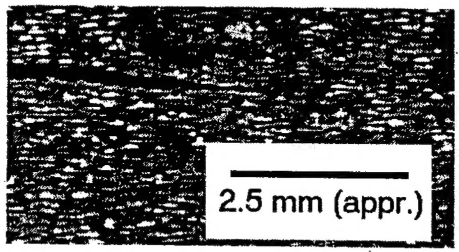
$$m = 1.902$$

Crack Growth Results

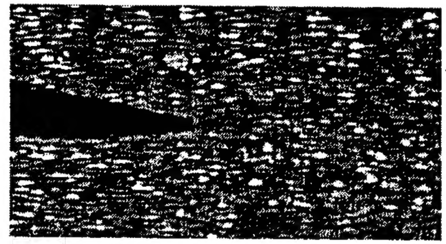
Effect of pressure is to slow crack growth

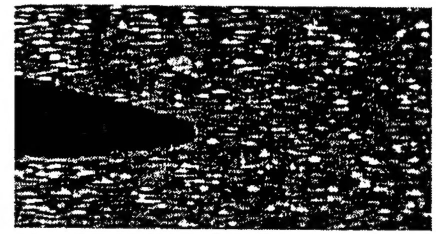


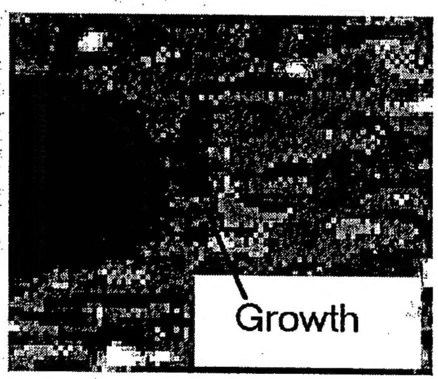
Crack Initiation and Growth in a Rubbery Particulate Composite



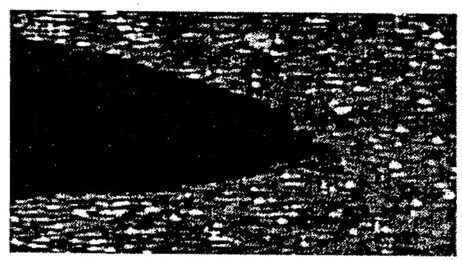
Crack just after loading begins

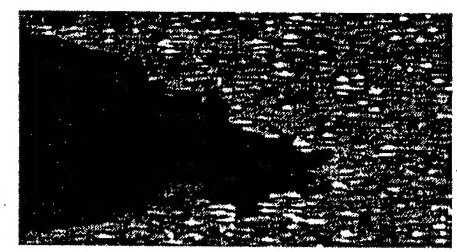

Continued loading


Continued loading with blunting



Close-up of crack at initiation of growth


Continued growth


Crack after extensive growth

Recommendations for Future Work

- Examination of short crack fracture phenomena
  - (Why do the short cracks behave differently?)
- Surface crack growth analysis
  - (Find a way to measure crack depth and width in pressurized environment)
- Link between microstructure and pressure effect
  - (Establish a connection between pressure effect and microstructural phenomena such as void nucleation, growth, and coalescence)